UNCLASSIFIED

TECHNICAL OPERATING REPORT

WDL-TR2025

25 JANUARY 1963

MAINTAINABILITY TEST AND DEMONSTRATION PLAN FOR NEW HAMPSHIRE STATION MULTI-SATELLITE AUGMENTATION PROGRAM, PHASE "A"

CONTRACT AF04(695)-113

WDL-TR2025
25 January 1963

TECHNICAL OPERATING REPORT

MAINTAINABILITY TEST AND DEMONSTRATION PLAN FOR NEW HAMPSHIRE STATION MULTI-SATELLITE AUGMENTATION PROGRAM, PHASE "A"

Prepared by

PHILCO CORPORATION
Western Development Laboratories
Palo Alto, California

D/C AF04(695)-113

Prepared for

SPACE SYSTEMS DIVISION
AIR FORCE SYSTEMS COMMAND
UNITED STATES AIR FORCE
Inglewood, California

ABSTRACT

PHILCO WDL-TR2025 UNCLASSIFIED
MAINTAINABILITY TEST AND DEMONSTRATION
PLAN FOR NEW HAMPSHIRE STATION
MULTI-SATELLITE AUGMENTATION PROGRAM,
PHASE "A" 54 pages
25 January 1963 Contract: D/C AF04(695)-113

This report outlines the procedures and techniques to be utilized in demonstrating the maintainability of the MUSAP "A" Timing and Control/Display Subsystems at the New Hampshire Station (NHS). The subsystem equipment is identified and the test conditions postulated.

THIS UNCLASSIFIED ABSTRACT IS DESIGNED FOR RETENTION IN A STANDARD 3-BY-5 CARD-SIZE FILE, IF DESIRED. WHERE THE ABSTRACT COVERS MORE THAN ONE SIDE OF THE CARD, THE ENTIRE RECTANGLE MAY BE CUT OUT AND FOLDED AT THE DOTTED CENTER LINE. (IF THE ABSTRACT IS CLASSIFIED, HOWEVER, IT MUST NOT BE REMOVED FROM THE DOCUMENT IN WHICH IT IS INCLUDED.)

FOREWORD

This Technical Operating Report, Maintainability Test and Demonstration Plan for New Hampshire Station, Multi-Satellite Augmentation Program, Phase "A" on Definitive Contract AF04(695)-113, is submitted in accordance with Exhibit "A" to said contract and Paragraph 3.16 of AFBM Exhibit 58-1 "Contractors Reports Exhibit," dated 1 October 1959, as revised and amended.

The report was prepared by the Philco WDL Maintainability Assurance Section, Human Factors and Operations Analysis Laboratory in fulfilling the requirements of MIL-M-26512B, Appendix A, "Maintainability, Test and Demonstration, Requirements for Systems and Equipments," and Paragraphs 4.1 and 1.2.3.1 of AFSSD Exhibit 61-27A, "Satellite Control Subsystem Work Statement," dated 15 February 1962, as revised and amended.

Supplements to this report will be issued as appendices.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF FORMS

SECTION 1
INTRODUCTION

1.1 SCOPE AND PURPOSE

The scope of this report is a description of the quantitative maintainability requirements test and demonstration plan for MUSAP "A". The plan, constituting one phase of the maintainability program described in "Philco Western Development Laboratories Maintainability Program," (Ref. 1) applies to the testing of the Timing and Control/Display Subsystems for MUSAP "A" as installed at the New Hampshire Station.

The purpose of the plan is to obtain a quantitative measure of the maintainability of the MUSAP "A" Timing and Control/Display Subsystems, to provide data to the Air Force which may form the basis for improvements in criteria and in design of future phases of the MUSAP, and to present recommendations for correction of design deficiencies observed in testing.

1.2 STEPS OF THE TEST AND DEMONSTRATION PLAN

The steps of the plan described in this report are:

- Establishment of test objectives.
- Specification of test conditions.
- Selection of test samples.
- Testing and collection of data.
- Analysis of data.
- Reporting of test and demonstration results.

1.2.1 Establishment of Test Objectives

The basic test objectives is to demonstrate, by measurement of active corrective maintenance downtime, that the maintainability goals for the subsystems are met.

In addition, qualitative aspects of system and equipment design affecting the measured active maintenance downtime will be evaluated and reported.

Improved of existing assurance methodologies is implicit in the test plan, with incorporation of experimental sampling and measurement teachniques subject to constraints imposed by the basic test objective.

Conduct of the test and demonstration program will also provide a basis for critical evaluation of those portions of MIL-M-26512B applicable to the program.

The basic test objective, performed to meet the explicit requirements of (Ref. 2) MIL-M-26512B, Appendix A, Para. 30.2.5, will be achieved through testing in the actual maintenance environment.

Secondary objectives will be achieved to the extent practicable during preparation for testing, testing and analysis, and, if feasible, by special tests.

Analysis of Trouble and Failure Reports (TFRs) generated on the equipment during installation, checkout and operation will be used to validate TFR times used as bases for requirements estimates or for maintainability monitoring subsequent to testing. This analysis will be conducted by comparison to demonstration data.

1.2.2 Specification of Test Conditions

The test conditions are considered to encompass:

- Identification of the equipments to be tested, and their functional relationship to the total system.
- Descriptions of the maintenance practices currently being implemented on equipment being tested.
- Definition of the skill levels of operation and/or maintenance personnel to be involved in test plan.

- Identification and assessment of maintenance support aspects, such as technical documentation, test equipment, spare parts, and maintenance tools and aids.

1.2.3 Selection of Test Samples

Test samples will be selected, guided by the procedures outlined in MIL-M-26512B, Appendix A, Para. 40.1.2. Modifications to these procedures primarily will involve: (a) selection of sample size to meet predetermined confidence limits, and (b) test realism.

The sampling will consist of selecting: (a) a set of tasks representative of the hardware population, and (b) the corrective maintenance problems that reasonably might be expected to arise in the equipment service life. This selection accomplished, the sample will be analyzed to determine the effect of the typical failure modes in the parts or units upon the system, and to devise the optimally effective method for simulating this failure.

Selection of simulation methods will be dependent upon the following criteria:

- Optimal absence of damage to the system; simulation of failure without permanent or expensive damage to other equipments.
- The maintenance task for correcting the simulated failure should be identical (or display only minor deviation) to the task required for an actual failure.
- All display, monitor, and test characteristics should be the same in simulated and actual failures.

1.2.4 Testing and Collection of Data

The methods developed for simulation of failures will be applied to the equipment. The elements of maintenance tasks required to restore the equipment to operating status will be observed, timed, and recorded, with any relevant remarks.

Other sources of data, such as station operating log books, TFRs, parts and tool lists, test equipment lists, and technical manuals, will be reviewed for applicable information.

1.2.5 Analysis of Data

Data analysis will be conducted under the initial assumption that the underlying distribution of measurements is exponential (Ref. 3,4); testing of alternative distributions will be carried out where necessary.

1.2.6 Reporting of Test and Demonstration Results

Reporting shall include, but not necessarily be limited to the following:

- Those parameters defined in the test objectives.
- Demonstration of attainment of specification goals.
- Comprehensive reporting of all items required by MIL-M-26512B, Appendix A, Para. 30.2.5.
- Critical review of all aspects of the test and demonstration program.
- Identification and review of methodology changes due to uncontrollable implementation variables of the test and demonstration program.
- Critical comparison of actual test conditions to anticipated conditions.
- Conclusions and recommendations including hardware design correction for improved maintainability.

SECTION 2
TEST OBJECTIVES

2.1 BASIC TEST OBJECTIVE

The basic test objective is to demonstrate that the specified maintainability goals for the Timing and Control/Display Subsystems in MUSAP "A" have been achieved. The parameters to be developed for this demonstration are described in the following paragraphs.

2.1.1 Fundamental Parameters

The fundamental parameters describing the subsystems are:

$$A = \frac{MTBF}{MTBF+MTR}$$

where A = Point availability; the probability that the subsystem will be available for an operational demand at any specified point in time.

MTBF = Mean-time-between-failures.

MTR = Mean-time-to-restore the subsystem to operation.

A and MTBF being established by subsystem specifications, MTR is derived by the following formula:

$$MTR = \frac{1 - A}{A} \quad MTBF$$

These goals, for the MUSAP "A" subsystem at New Hampshire Station (NHS), are as shown in Table 2-1.

2.1.2 Analytical Parameters

For purposes of determining MTR as identified in Para. 2.1.1, the following parameters will be derived in analysis (Ref. 1):

$\bar{M}_{ct}$ = Arithmetic mean corrective maintenance downtime.

M_{ct95} = 95^{th} percentile point of the distribution of corrective maintenance downtime.

P% interval = Interval about any sample point in which the corresponding population point has P/100 probability of occurrence. (confidence interval).

a. For the purpose of this test plan,

$\bar{M}_{ct}$ = MTR (active preventive maintenance downtime not being tested and measured).

Also: $\bar{M}_{ct} = 1/\zeta$ and $\zeta = 1/\bar{M}_{ct}$

where ζ (zeta) is the fundamental parameter of the exponential distribution

$$\exp(-\zeta t)$$

describing frequency of maintenance times.

b. For the exponential distribution:

$$\sigma = \mu$$

and

$$M_{ct95} = \mu + 2\sigma = 3/\zeta$$

c. For this test and demonstration, the estimated population points should fall within the interval about sample points defined by

$$P \pm \frac{M_{ct95} - \bar{M}_{ct}}{32} \times 5$$

with a probability of 0.90.

This is:

$$p - {}^{5}/16\zeta < \sigma < p + {}^{5}/16\zeta$$

2.1.3 Estimated Parameters

The parameters defined in Para. 2.1.2 are presented in Table 2-2 as derived from specifications and historical data using, where required, estimates drawn from knowledgeable sources.

2.2 SECONDARY TEST OBJECTIVES

2.2.1 Qualitative Evaluation

In the course of developing the demonstration test sample, a functional analysis of the equipment will be conducted. This analysis, in addition to outlining equipment-specific procedures in corrective maintenance will identify the incorporation (or lack of it) of maintainability design principles that would presumably aid (or hinder) the maintenance operation.

From this identification, the maintainability evaluator will be supplied with a set of test-specific questions leading, desirably, to the following points:

- If present, was the item used in the maintenance action? If not, why not?
- If absent, was the maintenance action hindered by this absence?
- What steps were taken to bypass this shortcoming?

2.2.2 Methodology Evaluation

Operations, methods, and analysis applied by the Maintainability Assurance Section in the course of implementing this plan shall undergo continuing review and assessment.

Where feasible, alternative techniques for particular phases of operation shall be identified and tested. These procedures shall include, but not be limited to, such items as:

- Alternative methods of test sampling.
- Fitting data to various types of distributions.
- Methods of simulated failure insertion.

2.2.3 Specifications Review

The outcome of the compliance demonstration tests is, in essence, a review of the basic maintainability requirement goals imposed on the equipment. Gross disparities between goals and measurements, assuming sound techniques of measurement, should initiate critical review of the specification (given goals much greater than measurements) or design review of the equipment.

Inasmuch as compliance to military specifications is a responsive process, the user should freely criticize any shortcomings or difficulties encountered in use, making his critique in such a manner as to constructively revise wording, format, or mode of application.

2.2.4 Historical Data

TFRs generated on the equipment during installation, checkout, and operation prior to the reporting date for demonstration tests will be analyzed for reporting confidence to be anticipated in TFRs. The TFRs will be maintained also as a historical source for data to be applied to future test and demonstration of MUSAP equipment.

TABLE 2-1

MTR GOALS

SUBSYSTEM	A	MTBF	MTR
Timing	0.9985	1000	1.50*
Control/Display (MTBF and MTR in Hours)	0.9990	1500	1.50**
* WDL Spec. 98-2047-09, Amendment 1. ** WDL Spec. 98-2048A-09			

TABLE 2-2

ESTIMATED PARAMETERS

Parameters	Timing Subsystem	Control/Display Subsystem
$\bar{M}_{ct}$	1.50 Hrs.	1.50 Hrs.
M_{ct95}	4.50 Hrs.	4.50 Hrs.
90% Confidence Limit	$\pm$ 0.469 Hrs.	$\pm$ 0.469 Hrs.

SECTION 3
TEST CONDITIONS

3.1 IDENTIFICATION OF ENVIRONMENT

Knowledge of the conditions under which simulated failure testing will be conducted is essential for proper control of the data. This is in the sense that measurements will be made upon sample elements affected by uniform conditions. To assure reasonable uniformity, the following test conditions are postulated:

- Detailed identification of equipment and its relationship to the system.
- The maintenance concept currently implemented at the station.
- Training and experience of station personnel assisting in test.
- Identification of maintenance support factors.

The functions of both subsystems to be tested are such that failure in either subsystem generally may be considered critical to mission success.

3.2 TIMING SUBSYSTEM (TS)

This subsystem provides timing signals and displays system time (Ref. 5). The major functional components for MUSAP "A" are

- Dual Time Generator.
- Time Display Generator.
- Time Display Distributor.
- Time Display Unit.
- Timing Terminal Unit.

These are organized as shown in Fig. 3-1. The basic design structure of the subsystem is characterized by printed circuit logic boards

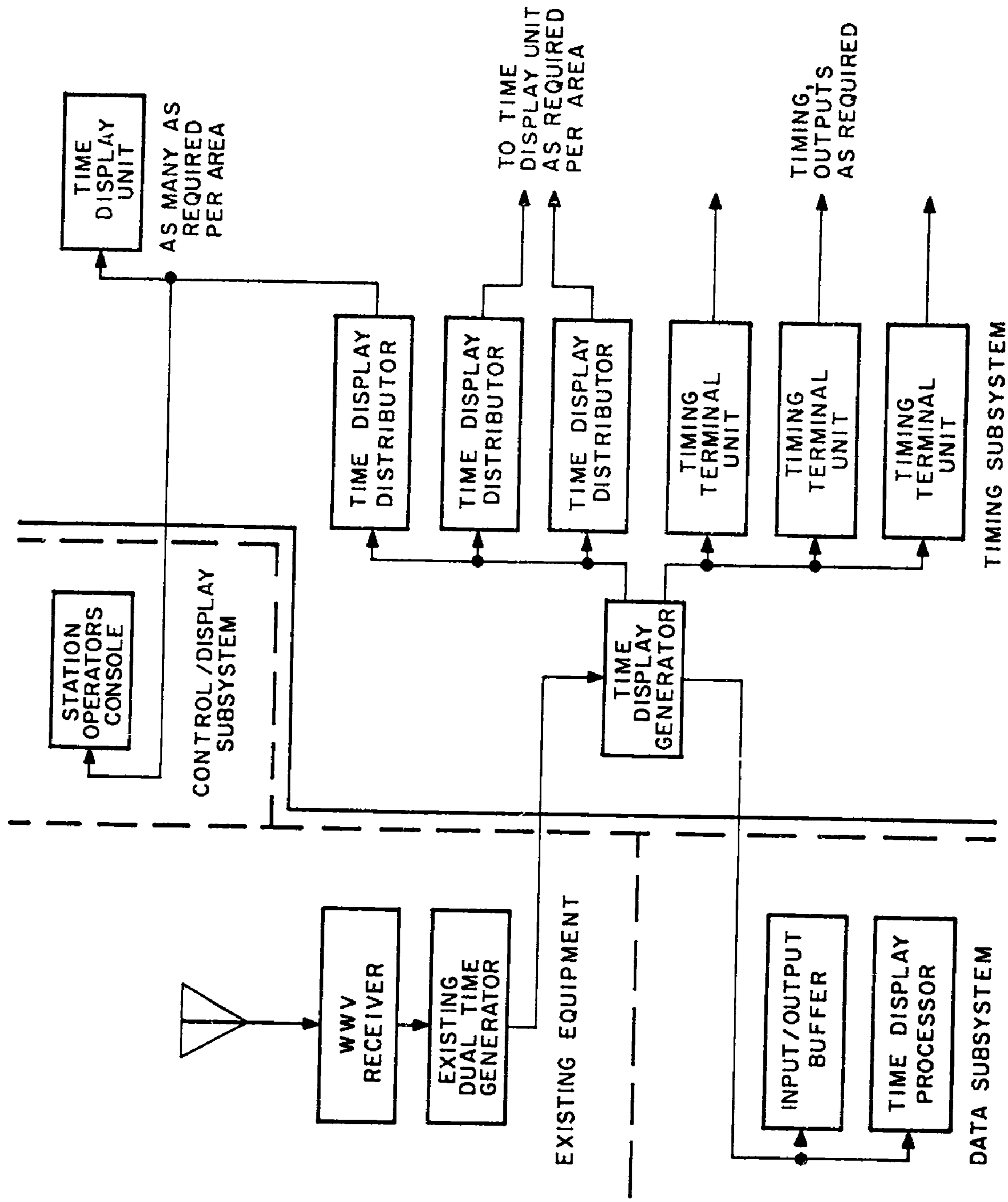


Fig. 3-1 Block Diagram of Timing Subsystem

(or cards). These are mounted in "files" containing 30 cards; the "files" in turn are assembled into "drawers" containing 3 to 11 files. Electrical contact is made via plug-in connectors mounted at the back of the "file" box. Minor variations of this assembly method may occur, dependent upon the circuit performance requirements.

3.2.1 <u>Dual Time Generator</u>

This component contains timing generators, a distribution unit, and a means of synchronizing system time to station WWV*. The generators are duplex redundant, one unit acting as a spare during operation of the other; the distribution unit selects generator output and automatically transfers to the spare if the selected unit fails.

3.2.2 <u>Time Display Generator (TDG)</u>

This component receives the time generator output and converts the signal to an increased bit rate for output to the Time Display Distributors.

3.2.3 <u>Time Display Distributor (TDD)</u>

This component receives the TDG output and converts it to parallel decimal form to drive a maximum of six Time Display Units.

3.2.4 <u>Time Display Unit (TDU)</u>

This component receives and displays the output of the TDD.

3.2.5 <u>Timing Terminal Unit (TTU)</u>

This component receives the TDG output and provides a set of standard frequency outputs.

3.3 CONTROL/DISPLAY SUBSYSTEM (CDS)

This subsystem provides the command and control capability for tracking and telemetry in the system, and displays station operating and equipment status (Ref. 6). The major functional components for MUSAP "A" are:

---

* National Bureau of Standards - Standard frequency signals

- System Operator's Console.
- Synchro Data Links.
- Station Program Board.

These are organized as shown on Fig. 3-2.

The basic design structure of the subsystem is characterized by piece parts assembled into modular panel groups with interconnection provided by taper pin connectors.

3.3.1 System Operator's Console

This component contains control and display equipment sufficient for three operators to monitor and control the following subsystems:

- Radar Tracker Antenna.
- Telemetry Tracker Antenna.
- Ground Telemetry.
- Data Handling.
- Timing.
- Checkout.
- Communication.

A Vehicle command (analog or digital) capability is also provided.

3.3.2 Synchro Data Links

These components provide isolation and phase balancing of synchro cable, perform T&D antenna 3-axis to 2-axis conversion and provide synchro inputs to the telemetry antennas. The links are terminated at the Station Program Board so that any antenna may be selected as a master unit for synchronous driving of other antennas in the system.

3.3.3 Station Program Board

This component provides the capability to configure two tracking and command complexes on one programmable patch board within the station.

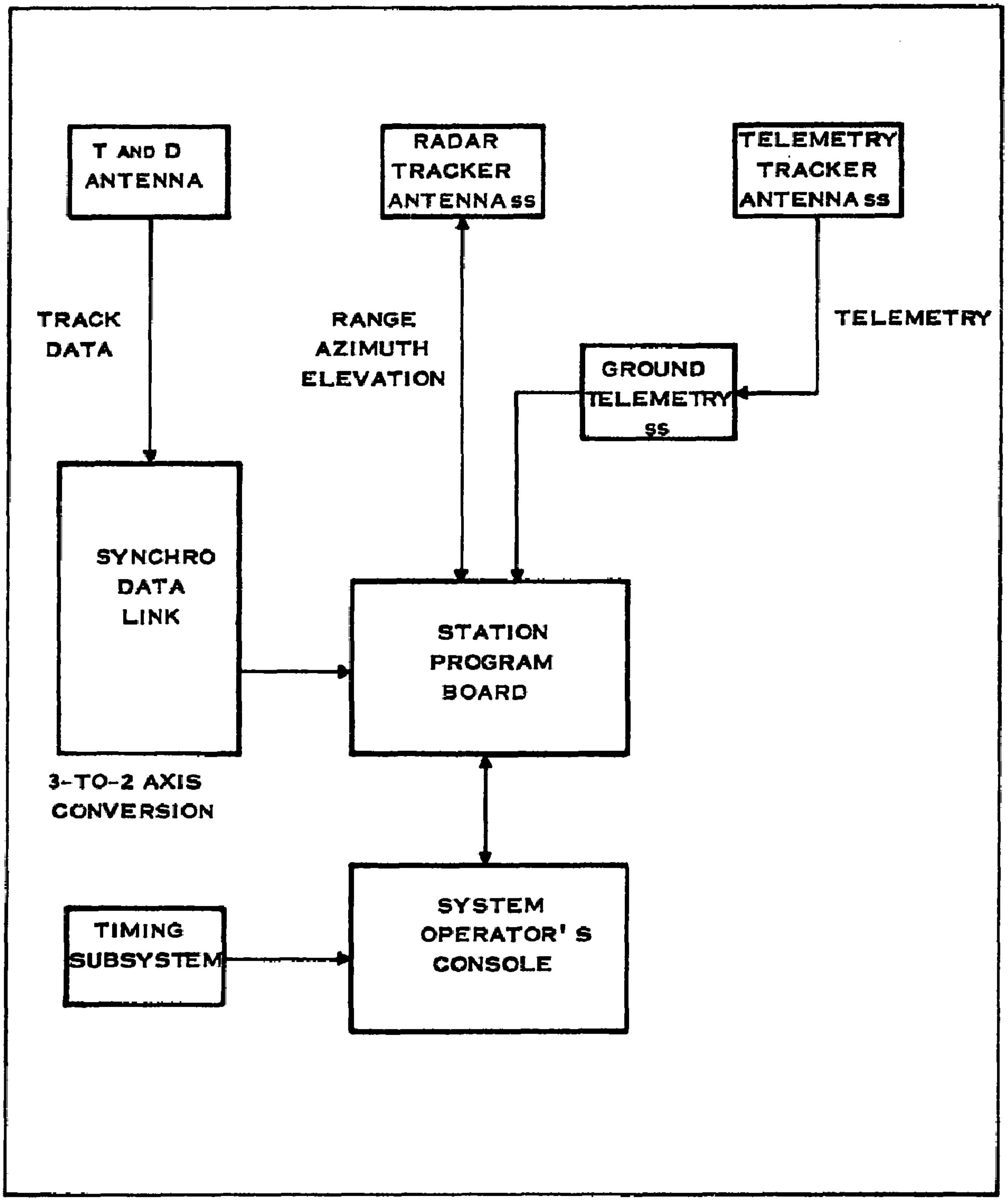


Fig. 3-2 Block Diagram of Control/Display Subsystem

3.4 PHYSICAL CONFIGURATION

The physical configuration of equipment, and location within the station, may have major effects on corrective-maintenance times. Points to be considered in connection with such effects are:

- Communication between maintenance personnel.
- Displays, indicators, test and monitoring points physically separated from point of failure.
- Physical and functional interrelation with other equipment.
- Ease of access for troubleshooting, correction, and checkout.

3.4.1 Timing Subsystem

The timing subsystem has a central generation and control group, with distribution and display components located at strategic points throughout the station (Fig. 3-3). The components are assembled into cabinets as illustrated in Fig. 3-4.

3.4.2 Control/Display Subsystem

The system-operator's console and the station program board are centrally located with synchro data links leading to, or installed on, the equipment subject to this control mode (Fig. 3-5). The console and program board are integral units containing modular subassemblies as illustrated in Fig. 3-6.

3.5 MAINTENANCE CONCEPT

The maintenance concept implemented at the station is a composite reflecting the basic outlines of intent, purpose, and practice. Intent is clearly stated as design for maintaining the station in operating status. Purpose is simply defined as meeting the operational requirements imposed on the station. Practice is the definition of methods as affected by design, technical training, logistics, test equipment, maintenance aids and tools, and technical references. Hence, in a sense, the postulation or identification of conditions for this test plan, and the development of methods as affected by these conditions constitutes a testing concept.

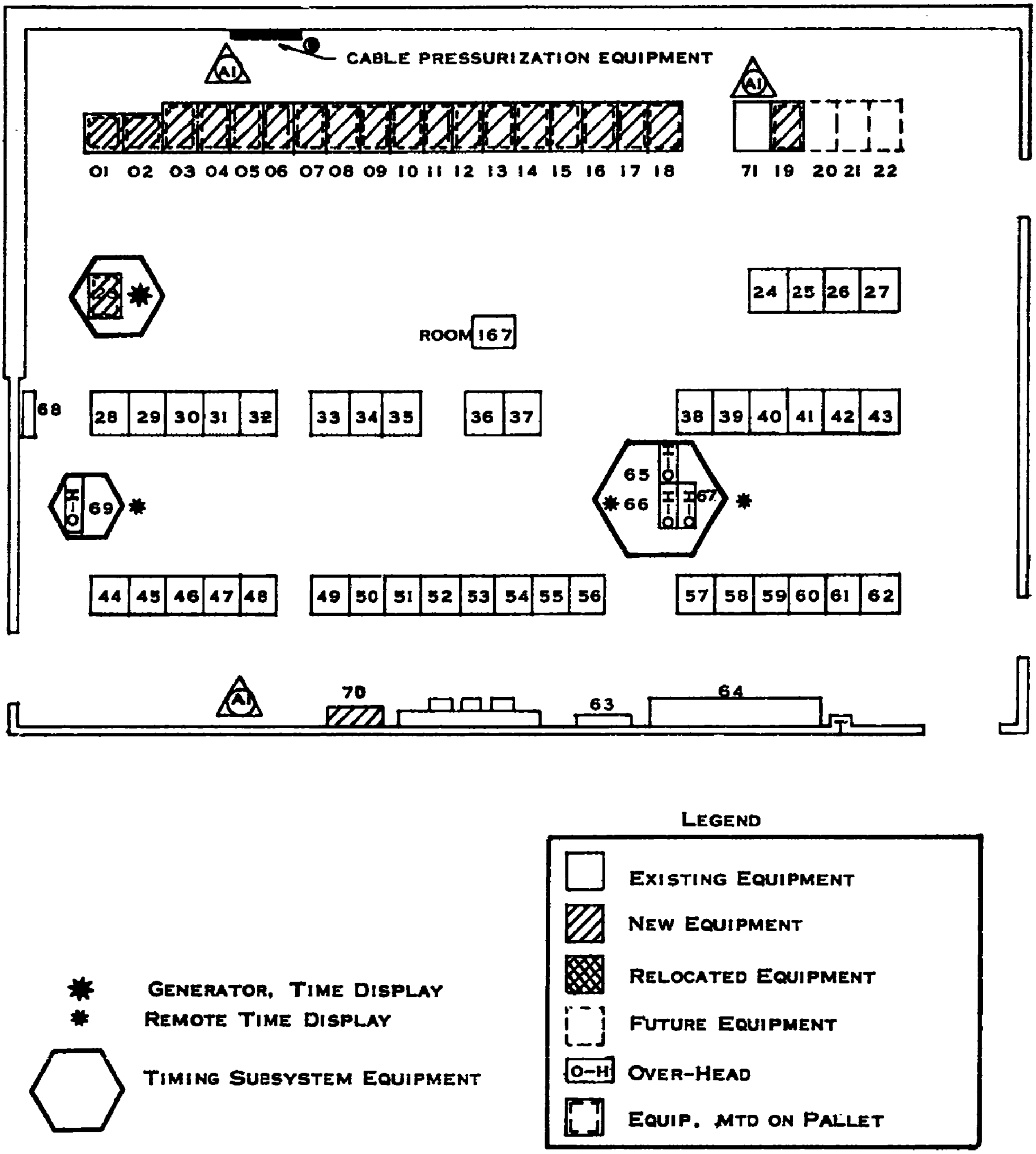


Fig. 3-3 Timing Subsystem Component Distribution at NHS

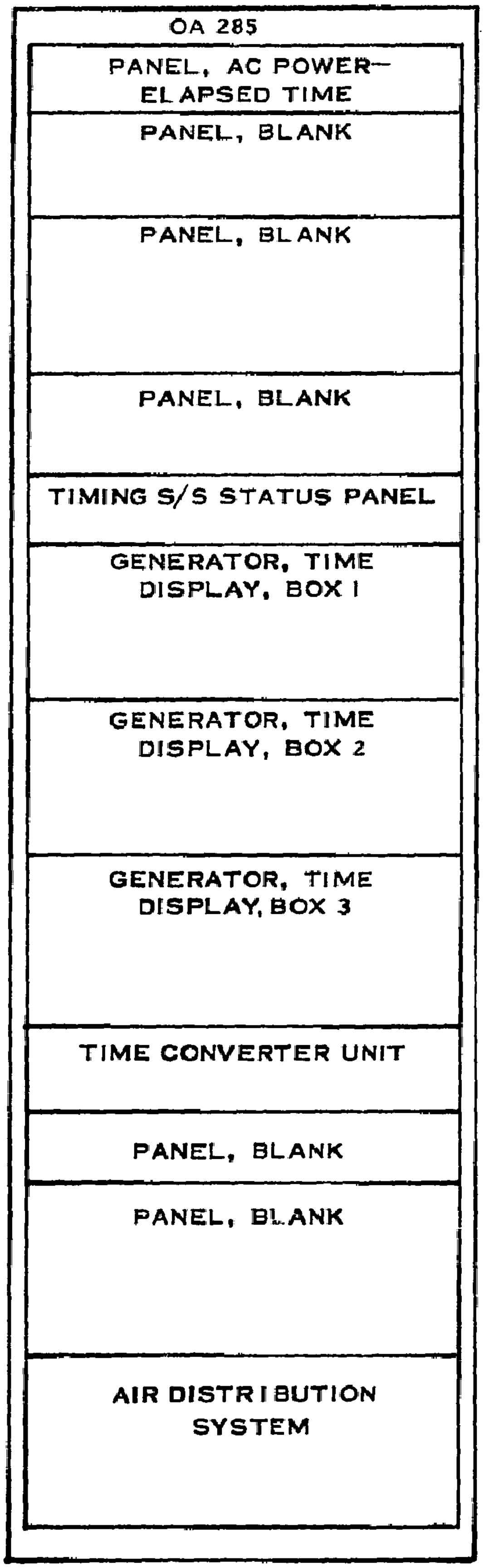
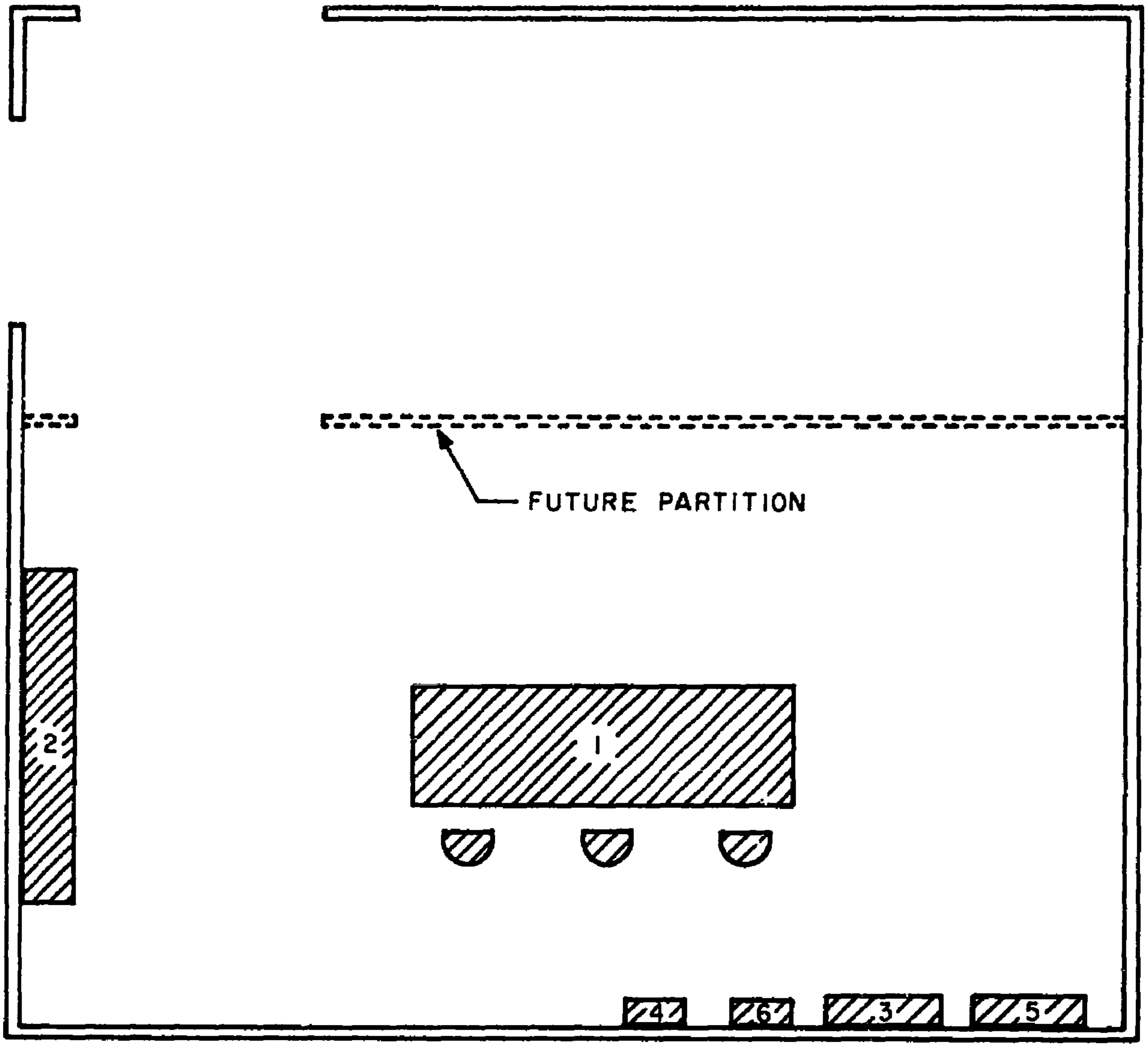


Fig. 3-4 Timing Subsystem Components at MHS



UNIT NO	DESCRIPTION
1	SYSTEM OPERATORS' CONSOLE
2	STATION PROGRAM BOARD
3	CABLE TERMINATION CABINET
4	SYNCHROLINE BALANCING UNIT
5	CABLE TERMINATION CABINET
6	SYNCHROLINE BALANCING UNIT

Fig. 3-5 Control/Display Subsystem Component Distribution at NHS

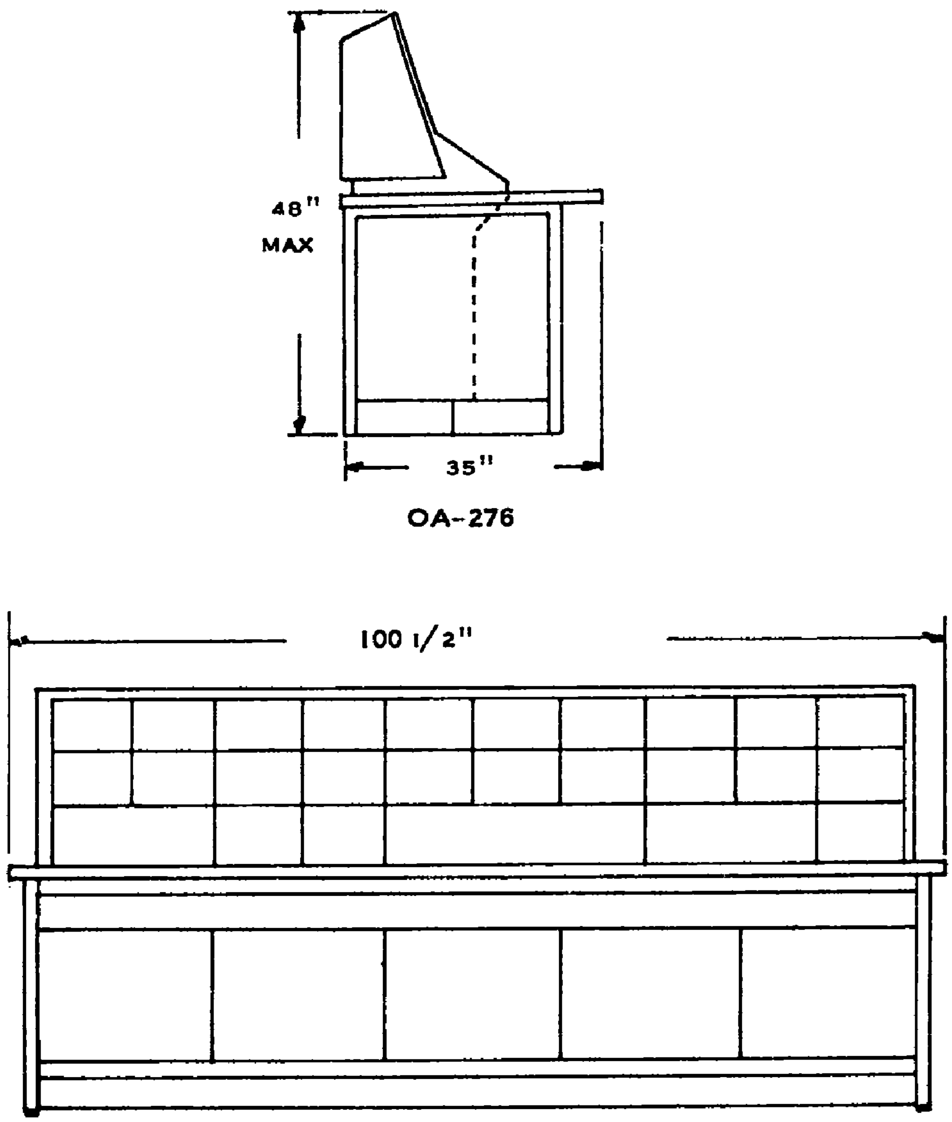


Fig. 3-6 System Operator's Console at NHS

For the sake of brevity, only those definitions and practices to be encountered in testing shall be identified in this section.

3.5.1 Maintenance Level

In measuring active corrective maintenance downtime, only organizational level maintenance will be employed in testing.

3.5.2 Maintenance Task Phases

Phases of the maintenance task (Para. 5.1.1) will be affected by the equipment design and location in the system:

- Diagnosis shall be carried out with the aid of displays, indicators, test points, and monitoring points.
- Restoration shall be accomplished by adjustment, or removing and replacing line replaceable units.
- Checkout shall be accomplished by determining that detection displays and indicators have been returned to normal operating status and that the system can return to acceptable readiness or operational state.

3.5.3 Maintenance Practices

Troubleshooting routines and correction practices will be those representative of the training and skill level of the maintenance personnel and commensurate with the system and equipment design. These practices, with exceptions clearly identified and documented, shall be presumed equivalent to those in general use.

3.6 MAINTENANCE PERSONNEL

The personnel presently assigned to the station subsystems will perform the corrective maintenance actions. These personnel customarily function as operator/maintainers under a subsystem supervisor. Training, skill level, and experience of these personnel will be considered equivalent to the level of qualifications cited; i.e., basic training in electricity and electronics, and 3 to 6 years of practical experience, with specialized training on assigned subsystems.

3.7 MAINTENANCE SUPPORT FACTORS

Factors identified for the purpose of this test plan as contributing to support of maintenance are:

- Spares supply.
- Test equipment.
- Maintenance aids and tools.
- Technical reference documents.

3.7.1 Spares Supply

The purpose of this test plan does not include evaluation of logistics policy or procedures. Thus, testing shall be conducted under the assumption that replacement spares for the failure simulated are available. Exceptions observed in testing will be dealt with in analysis and appropriate adjustment applied to time measurement records.

3.7.2 Test Equipment

Test equipment of conventional types, such as multimeters, oscilloscopes, and vacuum-tube voltmeters, will be available. To aid testing, the equipment to be used will be present at the inception of testing and be presumed accurate to the calibration standards of the station. The test equipment specified for the subsystems is listed in Table 3-1.

3.7.3 Maintenance Aids and Tools

All maintenance aids peculiar to the subsystem are assumed to be a portion of the equipment delivered and to be stored in operating areas. Each technician will be equipped with an electronic technician's tool kit containing standard hand tools. Special tools required by equipment design or configuration will be stored in operating areas and will be available if required by the test.

TABLE 3-1

SUBSYSTEM TEST EQUIPMENT

Control/Display Subsystem	Timing Subsystem
-28 vdc power supply with 5 amp. capacity (Armour T225-B or equivalent)	One Oscilloscope (Tektronix 535)
Two Volt-ohm meters (Triplet 630-NA or equivalent)	One Plug-in Dual Track Amplifier (Tektronix Type CA)
Two control transformers (Bendix AY-2401C-10-D2 or equivalent) and one control receiver (Bendix AY-2401C-9-D3 or equivalent)	VTVM (Hewlett-Packard 400H)
115 Volt, 60 cycle, 50 to 100 VA Isolation Transformer (LJP-DS306 or equivalent)	
Resistive Bridge (ESI-250DA or equivalent)	
Oscilloscope (Tektronix 545A or equivalent)	
Vacuum Tube Voltmeter, VTVM (Hewlett-Packard 400H or equivalent)	

TABLE 3-2

SUBSYSTEM-TECHNICAL MANUALS

Manual No.	Title
WDL-TM-3109-4	Timing Subsystem Organizational Maintenance
WDL-TM-3122-3	Time Display and Terminal Equipment Field Maintenance
WDL-TM-3110-4	Control and Display Subsystem Organizational Maintenance
WDL-TM-3124-3	System Operator Console Field Maintenance
WDL-TM-3137-3	Synchro Data Link Equipment Field Maintenance

3.7.4 Technical Reference Documents

Technical manuals and other documents such as charts and diagrams required for corrective maintenance will be available at the test location. Technical manuals presently required will be (in preliminary form) in possession of station personnel during the test period. A list of applicable manuals is presented in Table 3-2.

SECTION 4
TEST SAMPLES

4.1 PURPOSE AND NATURE OF SAMPLING

The purpose of sampling is to obtain, by measurement of the sample, a representation of the population under study. For this plan, the intent is to derive by sampling and measurement, a set of parameters which will reflect the characteristics of a maintenance task population.

There are certain aspects associated with electronic maintenance tasks that should be considered:

a. In any equipment configuration, excluding the somewhat high failure rates peculiar to installation and checkout, and provided that wearout has not commenced, the part failures contributing to corrective maintenance task frequency will basically reflect parts population density and failure rates. This failure population would be proportioned on the basis of percentage contribution of each $n_i \lambda_i$, where n is the population and λ is the basic failure rate associated with the i^{th} part class.

b. The failure populations identified in (a) are random distributions where any particular part may fail with the probability

$$\frac{1}{n_i}$$

within a particular part class and time period. Under such a circumstance, existing evidence suggests that the frequency distribution of corrective maintenance task times will be exponential in nature, (Ref. 4).

c. Due to the uniform design characteristics, a relative degree of homogenity in maintenance times is expected on each subsystem.

From these considerations, a random sample stratified by $n_i \lambda_i$ (part population failure rate products) is to be chosen as a representation of the maintenance task time population. Further, the frequency distribution of corrective maintenance task times simulated by this sample will be considered to be exponential and analysis conducted in accordance with this assumption.

4.2 SAMPLE SIZE AND METHOD FOR SELECTION

The sample size is chosen under a number of constraints, such as:

- Accuracy of estimating interval for population mean.
- Significant values for dispersion coefficients.
- Time available for testing and analysis.

4.2.1 Size Constraints

The guidelines of Appendix A, MIL-M-26512B, suggest a minimum sample size of 50 based upon homogeneous electronic part populations.

An alternative method for estimating sample size is based upon the analytical parameters identified in Para. 2.1.2. These define the population mean as falling about the sample mean defined by the interval within $\pm$ 5% of the total sample range of measurement, as follows:

$$1/\zeta - 5/16\zeta < \mu < 1/\zeta + 5/16\zeta$$

As a computation (Ref. 7).

$$\text{Upper Confidence Limit (UCL)} = \frac{2^{N_c}/\zeta}{X^2_{2N_c,\ 1 - \frac{(1-\gamma)}{2}}}$$

$$\text{Lower Confidence Limit (LCL)} = \frac{2N_c/\zeta}{X^2_{2N_c,\ \frac{(1-\gamma)}{2}}}$$

where: N_c = number of tests

$1/\zeta = \bar{M}_{ct}$

$X^2_{2N_c}$ = X^2 value for $2N_c$ degrees of freedom at $(1 - \gamma)$ significance.

γ = Confidence level.

The derivation follows from the requirement that

$$\text{Max} \quad \left| UCL - {}^1/\zeta \ , \ {}^1/\zeta - LCL \right| \leq 5/16\ \zeta$$

and requires an iterative calculation based upon substitution of N_c into the confidence limit expressions.

4.2.2 Time Constraints

Clearly, under time constraints for testing, the sample size is chosen on the basis

$$N = \text{Min}\ (N_1, N_2)$$

where N_1 and N_2 are sample sizes selected by the methods cited. Sample sizing is illustrated in Table 4-1.

TABLE 4-1

SAMPLE SIZE

Given:

$$\xi = 1/1.50$$

$$5/16\xi = 0.469 \text{ Hrs.}$$

Upper Confidence Limit Required (UCL)	= 1.969 Hrs.	+5% of Measurement Range with 90% Confidence
Lower Confidence Limit Required (LCL)	= 1.003 Hrs.	

SAMPLE SIZE	UCL	LCL
$N_c = 10$	$\dfrac{2N_c/\xi}{X^2_{2N_c,\ 0.05}} = 2.765$	$\dfrac{2N_c/\xi}{X^2_{2N_c,\ 0.95}} = 0.955$
$N_c = 20$	2.263	1.076
$N_c = 30$	2.084	1.138
$N_c = 40$	1.986	1.178
$N_c = 42$	1.972	1.184
$N_c = 43$(Selected)	1.966	1.188
$N_c = 45$	1.954	1.194
$N_c = 50$	1.926	1.207

4.2.3 Sample Selection Method

a. Identify generic LRU classes.

b. Develop class population density count (n_i).

c. Assign basic failure rate to each class (λ_i)(see Tables 4-2 and 4-3). Follow guidelines of AD-148868, RADC Reliability Notebook.

d. Determine percentage contribution of each class to failure population and number of simulated failures per class by:

$$\frac{N\alpha}{N\ \text{total}} = \frac{n\alpha\,\lambda\alpha}{\sum n_i\,\lambda_i}$$

e. Assign a serial number (for identification) to each element of each class, and randomly select the LRUs in accordance with the proportioning outlined in (d).

f. Perform an analysis on the items selected to determine that failure may be simulated under the restrictions outlined in Para. 1.2.2. If these cannot be met entirely, discard the item(s) from the population (if selection probability is not significantly affected), repeat step (e) and completely document the rejection rationale.

4.3 SPECIAL TESTING

If certain low-population items are not selected in the sample, or sampled items are adjudged to possess exceptionally long M_{ct} (much greater than M_{ct95}); these items may be tested independently of the statistical sample and the results analyzed for their effect on the distribution.

4.4 SUBSYSTEM SAMPLING

The basic design characteristics of the equipment and the concept of maintenance at the station are prime determinates for sampling classes.

TABLE 4-2

TIMING SUBSYSTEM, CARD CLASS FAILURE RATES
Failure Rate Estimation "Ball-Park" Figure*

Card Number	Number Used In Subsystem	"Ball Park" Failure Rate (%/1000 Hrs)
Flip-Flop	53	4.80
Amplifier, Logic	46	3.49
Inverter	20	1.97
Driver, Clock	9	3.24
AND Gate	32	1.16
Amplifier, Line, -1 volt	1	2.45
Component, Blank	1	[illegible]
Amplifier, Squaring, -4 volts	2	0.99
Amplifier, Line, 600 ohms	2	0.75
Component, Type 7	1	0.05
Amplifier, Squaring	3	2.00
One-Shot	5	3.45
Oscillator, 400 KC	3	1.65
Driver, Line, 3 Mile	2	3.90
Component, Type 8	1	0.03
OR Gate	4	**
Filter	1	1.10
Modulation Amplifier, 4 to 1	1	1.52
Driver, Line, 600 ohms	3	1.30
Driver, Line, -12 volts	14	3.20
Component, Type 5	1	0.02
Driver, Line, -1 volt	4	3.18
Driver, Power, 1.5 amperes	10	3.16
Amplifier, Line, 3 Mile	1	1.05
Decoder, BCD to Decimal	5	3.40
Component, Type 6	1	0.04

* RADC Reliability Notebook, pp. 20, 21; 31 December 1961

** Not available at time of publication

TABLE 4-3

CONTROL/DISPLAY SUBSYSTEM, PART CLASS FAILURE RATES

Average Component Failure Rates (%/1000 hrs)*	
Component	Rate
Transistors	0.1
Tubes	1.0
Resistors	0.04
Capacitors	0.01
Relays	0.1
Semiconductor Diodes	0.05
Transformers and Coils	0.03
Connectors	0.02
Switches	0.1
Blowers and Motors	0.5
Miscellaneous	0.2

* Taken from RADC Reliability Notebook, pp. 20, 21, 31 December 1961

4.4.1 Timing Subsystem

The Timing Subsystem (Para. 3.2) LRUs primarily consist of card electronics; therefore, sampling will be conducted at card level and a nominal basic failure rate for each card class developed for valid stratification (see Table 4-2).

4.4.2 Control/Display Subsystem

The Control/Display Subsystem LRUs are primarily electronic piece parts; therefore, sampling will be conducted at part level, and basic failure rates for each part class identified drawn from the RADC Reliability Notebook (Table 4-3) or WDL Reliability Reports with stratification in step (c) additionally weighted by MTR estimate for part class. (Table 4-4).

4.5 SELECTED SAMPLE

The sample selected for testing, with an outline of the simulation method to be applied for each test will be submitted to the customer for approval prior to testing. Format shall be as separately delivered appendices to this test plan.

TABLE 4-4

$\bar{M}_{ct}$ ESTIMATES

Part	Hours
Capacitors	2.2
Diodes	1.2
Relays	0.5
Resistors	1.4
Tubes	0.7
Switches	0.5
Transformers	1.2
Transistors	1.2
Connectors	1.5
Blowers and Motors	0.7
Meters	2.0
Fuses	0.2
Amplifiers (Unit)	1.0
Inductors	0.5

SECTION 5

TESTING AND COLLECTION OF DATA

5.1 TESTING

The simulation method determined for each test selected in the sample will be applied to the equipment, and the time required to restore the subsystem to operating status measured.

5.1.1 Significant Test Measurements

a. General: The fundamental parameter to be developed is active corrective maintenance downtime. In making time measurements, the following contributory time intervals shall be excluded:

- Time for procurement of spares.
- Administrative time, such as coffee breaks, meals, personal convenience and paper work.
- Time for procurement of maintenance support material.

The following sequential time phase of maintenance tasks shall be identified and measured, noting the exlusions previously defined:

- Diagnosis.
- Restoration.
- Checkout.

b. Diagnosis: Diagnosis time is the time interval between detection and identification of the specific failure to be corrected and its physical location in equipment. In the context of this plan, diagnosis shall be defined as follows:

- For the timing subsystem, identification of failure to the replaceable chassis/card level.

- For the control/display subsystem identification of failure to the replaceable piece part level.

c. Restoration: Restore time is the time interval required after diagnosis to correct the failed equipment by removing and replacing LRUs.

d. Checkout: Checkout time is the time interval required to assure that the subsystem is operating normally following repair activities. For the purposes of this test, the maintainer will be instructed to announce the completion of verification; this will be checked against a previously developed tabulation of normal subsystem operating mode indications.

e. Detection: Detection time will not be measured. In standard operating practice, detection of a malfunction or failure initiates the corrective maintenance sequence, and no sound method presently exists for determining the point in time at which the malfunction or failure occurred. Thus, any method applied to determine the length of detection time intervals would only produce an estimate based solely on the testing method.

5.1.2 Methods

The following method of initiating the test shall be employed:

- The maintenance personnel will be instructed to monitor the equipment and initiate corrective action on detection of failure.

In a properly sequenced corrective maintenance task, the task phases as defined should be measured without difficulty, and the times recorded on the form illustrated in Fig. 5-1.

If the checkout step chosen by the technician indicates that the inserted simulated failure was not corrected, the following steps will be taken:

- The technician will be informed that the task has not been completed satisfactorily and requested to re-inititate the diagnostic phase of the maintenance task.
- The replaced LRU will be examined. If a failure does not in fact exist, the elapsed time shall be recorded as diagnostic time in continuation of the test.

5.2 COLLECTION OF DATA

5.2.1 Quantitative Measurements

Time measurements will be recorded on Form 5-1. The entries on this form are self-explanatory. For uniformity of reporting, all time entries shall be on the # 0001-2400 hour scale. Intervals of time not contributing to active maintenance downtime should be carefully identified, fully explained, and recorded.

5.2.2 Qualitative Data

Remarks responsive to the qualitative evaluation objective outlined in Para. 2.2.1 will also be entered on the time measurement form (Form 5-1), and referenced to the test-specific questions developed in maintenance analysis of the test sample.

5.2.3 Preliminary Evaluation

Equipment in the subsystems was qualitatively evaluated prior to shipment from Philco WDL. These data will provide an additional source of information for use in the analysis and reporting phase of this demonstration. A sample of this type of evaluation record is illustrated in Form 5-2.

5.2.4 Trouble and Failure Reports (TFR)

Data from TFRs generated to completion of testing will be analyzed, for comparison with sample measurements. Where practicable during testing, methods of reporting TFR's will be reviewed to determine acceptability as source data for historical records.

FORM 5-1

TEST OBSERVATION RECORD

A. SIMULATED FAILURE DATA SHEET

OBSERVER:____________________ DATE: ________________

LOCATION

Subsystem:__________________________

Cabinet | No.________________ Name______________

Panel | No.________________ Name______________

| WDL Model No.__________________________

Circuit Board (when applicable) | File No. __________________________

| Location No. _____________ Part No. ________

FAILURE SIMULATION

Type of failure simulated:__________________________

Method of simulation:____________________________

Designation of piece part simulating failure:_____________

Symptoms of fault insertion:_________________________

____

Mode of operation at detection:______________________

____

TIME DATA

Real Time	
Start of Exercise	
Detect	

Time at End of Phase

Diagnosis	Localization			
	Isolation			
Repair				
Checkout				

FORM 5-1 (CONT'D)

TEST OBSERVATION RECORD

B. COMMENTS

Administrative

Time Record

Out__________
In__________

Out__________
In__________

Out__________
In__________

Out__________
In__________

Out__________
In__________

FORM 5-1 (CONT'D)

TEST OBSERVATION RECORD

C. PERSONNEL DATA SHEET

Name______________________ Age________ Date____________

Tech Rep ☐ Job Classification__________ Type of Work____________

Military ☐ Rank______________ Type of Work____________________

Educational Record (Note grade completed

High School__________ College__________ Grad School________

Technical Schools and/or course name

	Duration

MILITARY TRAINING

Branch of Service	Name of School	Duration

EXPERIENCE (Civilian and/or Military)

Company/Branch of Service	Job Title/Rank	Type of Work	Duration

FORM 5 2

MAINTAINABILITY DESIGN EVALUATION FORM

Evaluator: ____________________ Consultant ____________________ Date ____________

Program: ____________________ S/S ____________________ R ____________

ITEM OF HARDWARE / MAINTAINABILITY CHARACTERISTICS	A ACCESSES	B DISPLAYS INDICATORS	C CONTROLS ADJUSTMENTS	D OVERLOAD DEVICES	E TEST POINTS	F CONNECTORS	G WIRE CABLES	H MODULES CHASSIS	J CASES COVERS	K MISCELLANEOUS PARTS	L PM SERVICE ITEMS	OTHER			
1 Accessibility															
2 Color Coding	X								X						
3 Labelling															
4 Modularization	X		X	X	X	X	X		X		X				
5 Physical Alignment, Mounting			X		X										
6 Standardization	X		X				X		X						
7 Functional Arrangement	X						X		X						
8 Handling	X	X	X	X	X	X	X				X				
9 Maintenance Automaticity	X	X	X	X	X	X	X	X	X	X	X				
10 Maintenance Aids	X	X	X	X	X	X	X	X	X	X	X				
11 Safety															

KEY. 0 - Not incorporated 2 - Moderately incorporated 4 - Completely incorporated
1 - Slightly incorporated 3 - Almost incorporated Whenever not required add "NR"

COMMENTS & RECOMMENDATIONS:

QUES.
NO.

WDL-T-2132
11-62

FORM 5-2 (CONT'D)

MAINTAINABILITY DESIGN EVALUATION QUESTIONS

1. Accessibility. Is access to all items requiring access adequate for visual and manipulative tasks?
2. Color Coding. Are all items requiring color coding so coded?
3. Labelling. Are all items labelled with clearly visible full identifying information? (Functional and coded)
4. Modularization. Have items been sufficiently physically integrated into easily replaceable units which will be made available as spares?
5. Physical Alignment, Mounting, Mating, Fastening, Keying. Is removal, replacement, assembly and dissasembly of items facilitated by adequate attention to item characteristics which enhance each of the above?
6. Standardization. Have items been standardized to facilitate interchangeability, compatibility, and to reduce the logictics burden?
7. Functional Arrangement. Have items been functionally arranged and grouped to facilitate accomplishment of maintenance tasks?
8. Handling. Where required, have items been provided with a means for grasping them, such as handles etc., to facilitate their removal, replacement and handling?
9. Maintenance Automaticity. Have adequate automatic and semi-automatic features been incorporated to permit achievement of MTR goals? Included are fault and operating indicators to eliminate or reduce need for test equipment, or where test equipment is required is it easy to use (automatic, built-in etc.).
10. Maintenance Aids. Has the need for supplementary items such as jigs, fixtures, test equipment, adaptors, extension boards etc., been minimized or where required, provided?
11. Safety. Has the equipment been designed to minimize danger to maintenance personnel during performance of maintenance tasks? (Covers, guards, shields, proximity to high voltage, temperature, radiation and moving parts, warning plates, shorting bars, sharp protrusions, etc.).

5.3 TEST SCHEDULING

5.3.1 Personnel Requirements

The number of tests required for relevant data production is outlined in Para. 4.2.1. Experience indicates that collection (on a non-interfering basis) of the data volume required should extend over a period of one calendar month, and require the following personnel:

- Test and evaluation coordinator.
- Two or more test and evaluation observers.

Assistance from station personnel will involve the services of the subsystem supervisors to review and insert simulated failures and of technicians to perform the maintenance tasks.

5.3.2 Test Period

The test period will be scheduled to commence on 4 March 1963 and end on 5 April 1963. Specific sequence of simulated failure insertion shall be at the option of the test coordinator. Where time, personnel, and operating conditions permit, subsystems shall be tested concurrently and independently.

To provide a basis for judging the emphasis to be placed on the test, the test coordinator shall compare $\hat{M}_{ct}$ for the test completed to the estimated confidence interval for $\dot{M}_{ct}$ (Table 4-1). This comparison shall be conducted at the completion of each block of ten tests, and develop the cumulative $\hat{M}_{ct}$ at that point.

If $\hat{M}_{ct}$ (measured) consistently falls in an interval of greater magnitude than the confidence interval ($< \mu_{max}$), increased attention should be given to those qualitative aspects of equipment design (specific to the test) that appear to be hindering effective maintenance.

If $\bar{M}_{ct}$ consistently falls into an interval of lesser magnitude than the confidence interval ($< \mu_{min}$), simulated failure insertion may be accelerated.

SECTION 6
ANALYSIS OF DATA

6.1 PURPOSE

6.1.1 Parameters

The basic purpose of data analysis is to produce by means of universally accepted techniques, a set of experimental parameters (Para. 2.1.2) from the measurements described in Section 5. These parameters will be compared with those derived from specifications to determine whether the basic test objective requirements are met.

6.1.2 Secondary Objectives

Secondary objectives will be measured or evaluated by methods compatible with their information content (Ref. 4).

6.2 ASSUMPTION FOR ANALYSIS

Analysis of the quantitative measurements will be conducted under the assumption that the data developed is exponential in nature (Refs. 3,4).

6.2.1 Implications of Assumption

The exponential assumption describes the measurement distribution by

$$F(t) = \exp(-\zeta t)$$

where:

$$\zeta = 1/\dot{M}ct$$

This is a real-time distribution and is not subject to certain of the potential pitfalls of log-normal analysis. The parameters developed under this assumption are analytically tractable and well-defined. Data reduction and analysis are simplified and time in analysis is reduced by a significant percentage.

6.2.2 Validation of Assumption

The assumption of exponential distribution of measurements shall be tested by applying the Kolmogorov-Smirnov test for goodness of fit of the sample measurements to the cumulative exponential distribution defined by

$$cum\ (t) = 1 - exp\ (- \zeta\ t)$$

at the 95% confidence level.

6.3 EDITING OF DATA

Time measurement data shall be edited to assure that:

- The requirements of Para. 1.2.3 (selection of simulation methods) were met.
- The measurement requirements of Para. 5.1.1 were met.

6.3.1 Ordering of Data

When editorial analysis is completed, the following steps shall be carried out:

a. Order sample by time magnitudes.

b. Determine cumulative frequency percentage of each measurement.

c. Determine number of intervals in distribution by

$$N_I \geq (1 + 3.3 \log_{10} N_c)$$

where:

N_c - number of tasks measured.

N_I - smallest integer enclosing formula product.

6.4 COMPUTATION

The following parameters shall be derived by computation (Para. 2.1.2):

- $\bar{M}_{ct}$ - arithmetic mean corrective maintenance downtime.

- M_{ct95} - corrective maintenance downtime enclosing 95% of measured tasks.
- Confidence interval enclosing measurement parameter points.

6.4.1 Formulae

The following computational formulae shall be applied to derivation of the listed parameters.

a. $$\bar{M}_{ct} = \frac{\sum_{1}^{N_c} M_{ct_i}}{N_c}$$

where: M_{ct_i} = the measured active corrective maintenance downtime for the i^{th} task.

N_c = the total number of tasks undergoing analysis.

b. $$M_{ct95} = 3\,\bar{M}_{ct}$$

by definition of the exponential distribution.

c. Confidence interval about .

$$UCL = \frac{2N_c/\zeta}{X^2_{2N_c,\ 0.05}}$$

$$LCL = \frac{2N_c/\zeta}{X^2_{2N_c,\ 0.95}}$$

$X^2_{2N_c}$ = the X^2 value for $2N_c$ degrees of freedom at the significance shown.

d. $\zeta = 1/\bar{M}_{ct}$

where: ζ = the exponential parameter

e. $s\,(\zeta) = 1/\zeta = \bar{M}_{ct}$

f. $P_{95} = 3/\zeta$

g. $$\bar{M}^{g}_{ct} = \frac{\ln 0.50}{-\zeta}$$

where. ln = natural logarithm

6.4.2 Auxiliary Formulae

The following computational formulae shall be applied to

- Validation of distribution assumption.
- Proportioning of maintenance task time phases.

a. The computed normal distribution is derived by:

cum $(t) = 1 - \exp(-\zeta t)$

and the measurement distribution tested for fit by

$$D = \max \left| F_o(t) - S_N(t) \right|$$

where: t = The measured time.

F_o = The computed ordinate.

S_N = The observed ordinate.

The sampling distribution of D is known; given N_c cases and a degree of significance α D_{max} (only) $> F(N_c\ \alpha)$ leads to accepting the hypothesis of the assumed distribution with a confidence $(1 - \alpha)$.

b. Proportioning of maintenance task phases is computed by:

$$\frac{\sum_{i}^{N_c} t_i(j)}{\sum_{j}\sum_{i}^{N_c} t_{ij}} \times 100 = \% t_j$$

where: j = Diagnosis; repair; checkout.

i = Individual tasks measured.

6.5 ANALYSIS OF DATA

The parameters derived from the measurements will be compared to those generated as estimates relative to test objectives (Table 2-2). Two outcomes are apparent.

6.5.1 Specification Goals Achieved

If comparison of parameters indicates that specification goals have been achieved, data acquired as a secondary objective (Para. 2.2) will be presented as supplementary information.

6.5.2 Specification Goals Not Achieved

If comparison of parameters indicates that specification goals have not been achieved, data required as a secondary objective shall be exhaustively analyzed to determine those design-specific aspects contributing to excessive corrective maintenance downtime.

SECTION 7

REPORTING

7.1 GENERAL

Reporting shall include, but not be limited to the following:

- Those parameters defined in the test objectives.
- Demonstration of attainment of specification goals.
- Comprehensive reporting of all items required by Appendix A, MIL-M-26512B, Para. 30.2.5.
- Critical review of all aspects of the test and demonstration program.
- Identification and review of methodologies applicable to, but developed after inception of the test and demonstration program.
- Critical comparison of actual test conditions to anticipated conditions.
- Conclusions and recommendations.

7.2 OUTLINE OF REPORT

Abstract

Foreword

Sections:

1. Introduction
2. Analysis and Results
3. Conclusions and Recommendations
4. References

Appendices:

A. Test Conditions

B. Quantitative Measurements

C. Secondary Objectives

D. Critique

7.2.1 Introduction

Section 1 will contain a brief review of the objectives, methods, and test and demonstration program, with tabulated comparison of the specified and measured goals.

7.2.2 Analysis and Results

Section 2 will contain an analysis of the quantitative measurements with detailed tabulated comparison of estimated and measured analytical parameters, and specified and measured goals. In addition, task-time percentages will be reported and discussed, and validation of analytical assumptions demonstrated.

7.2.3 Conclusions and Recommendations

Section 3 will contain a set of conclusions drawn from the body of the report and the appendices. Design recommendations will be presented as findings if goals are achieved, or as design-specific recommendations in the event goals are not achieved. Other recommendations will be drawn from the critique

7.2.4 Appendices

- Test conditions will present only those identified deviations from the conditions assumed for the test plan.
- Quantitative measurements will report each maintenance task in full detail, including task phase times. The full body of the quantitative analysis will be reported in this appendix in company with all charts, tables, and graphs developed in computation.
- Secondary objectives attained will be reported in detail, in a format suitable to the subject matter.
- Critique will encompass all circumstances and characteristics, favorable or unfavorable, of the factors affecting the test and demonstration. In addition, methods not specifically identified in the test plan will be reviewed.

SECTION 8
REFERENCES

1. Philco Western Development Laboratories Maintainability Program, WDL-TR1708A, Philco Western Development Laboratories, Palo Alto, California, April 1962.

2. Maintainability Requirements for Aerospace Systems and Equipment, MIL-M-26512B, USAF, Appendix A. "Maintainability Test and Demonstration Requirements for Systems and Equipments," 23 March 1962.

3. Exponential Distribution Analysis of Corrective Maintenance Times, by James W. Cresson, WDL-M-TM-5, Philco Western Development Laboratories, Palo Alto, California, January 1963.

4. Maintainability Evaluation Report, North Pacific Tracking Station, Program 461 Philco Western Development Laboratories, Palo Alto, California.

5. Timing Subsystem Specification, WDL-98-2047-09 Philco Western Development Laboratories Palo Alto, California, 23 November 1962.

6. Control and Display Subsystem Specification, WDL-98-2048-09, Philco Western Development Laboratories, Palo Alto, California, 10 August 1962.

7. Basic Statistical Concepts of Reliability, by F. M. Gryna, Jr., The Martin Company, Baltimore Maryland.

DISTRIBUTION LIST

Address	No. of Copies
Commander Space Systems Division Air Force Systems Command Air Force Unit Post Office Los Angeles 45, California Attn: Technical Data Center	10
USAF Contract Support Detachment No. 3 Philco Corporation Western Development Laboratories Palo Alto, California (D. Cowart)	1
Commander 6594th Aerospace Test Wing Sunnyvale, California	5
Aerospace Corporation (SCF/CSETD) P. O. Box 95085 Los Angeles 45, California Attn: C. M. Beyer C. Hoff	 1 1
Lockheed P. O. Box 504 Sunnyvale, California Attn: J. E. Mangelsdorf J. S. Lukascewski P. B. Zydner	 1 1 1
ASTIA Arlington Hall Station Arlington 12, Virginia	10
Philco Corporation Western Development Laboratories Palo Alto, California	67 + 1 reproducible
Philco Corporation (Plant 50) 4700 Wissahickon Ave. Philadelphia 44, Pennsylvania Attn: D. Kinnier (Engineering)	1

DISTRIBUTION LIST (CONT'D)

Address	No. of Copies
Philco Corporation Computer Division 3900 Welsh Road Willow Grove, Pennsylvania Attn: S. D. Wanlass	1
Philco Corporation P. O. Box 311 Amherst, New Hampshire Attn: J. H. Moore, Station Manager	3
A. R. Blute	3
Activation Manager	1
Air Force Representative	1
	108 + 1 reproducible

UNCLASSIFIED

UNCLASSIFIED